Fisheries, wildlife, and conservation biology education in Australia: current challenges and future directions

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ABSTRACT

Fisheries Science, Wildlife Management and Conservation Biology are crucial to the Australian economy and society. Australian doctoral education in these fields assumes that students commence with well-developed relevant skills, or acquire them autodidactically or from their supervisors. We believe that such reliance on autodidactic approaches and supervisor direction are no longer adequate, and argue for compulsory coursework within doctoral programs.

Currently, most specialised education in quantitative methods, advanced genetic techniques (including population genetics) or human dimensions is provided in short courses or workshops, if at all. Short courses provide advanced technical knowledge (e.g., an advanced stock assessment workshop for fisheries scientists or population viability analysis workshops for conservation biologists), but they are voluntary. Multiple university and multiple discipline consortia could provide the compulsory postgraduate coursework needed for structured development of quantitative skills in Australian PhDs. Online education should be part of the solution, but it is not a panacea because some material should be taught in person for effective learning. Solutions can build on modified approaches used overseas and in other disciplines in Australia.

Key words: Fisheries, Wildlife Management, Conservation Biology, graduate education, professional doctorate.

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Introduction

Globally, there is a substantial, growing literature on change and innovation in the structure of higher degrees by research, especially in skills acquisition (Murtonen *et al.* 2008; Raman 2008; Lee and Aitchison 2009), the relative importance of coursework and research projects (Neumann 2009; Chiteng Kot and Henda 2012), integrating industry perspectives or professional experience (Costley and Stephenson 2009; Scott *et al.* 2009), interdisciplinarity (Lyall and Meagher 2012; Franklin *et al.* 2012), and supervisorial expertise and practice (Brew and Peseta 2009). Fisheries science, wildlife management, conservation biology and other sciences relevant to applied natural resource management integrate all these topics. These fields of science share several attributes: they are distinct fields heavily dependent on quantitative techniques (mathematics, statistics, spatial analyses, computational skills and molecular/genetics techniques, especially those related to the genetic connectivity of populations) that can be acquired in different ways; they relate directly to the workplace; they require an interdisciplinary education across biology, environmental science and sociology; and they rely on the pedagogical and disciplinary skills of the supervisors. Currently, these attributes are acquired primarily either through postgraduate study or through continuing education in the work place.

Australian postgraduate education is ill-suited to developing interdisciplinary and quantitative skills given the basic level of skills covered in many undergraduate degrees. It is based on traditions in the United Kingdom, which assume that candidates enter the research higher degree well-grounded in relevant skills (Evans 2007). This is questionable given the pace at which many techniques are developing – PERMANOVA, for example, is barely a decade old (Anderson 2001), Bayesian analyses are undergoing a resurgence in numerous forms (Woodward 2012) and new genetic analyses are developing speedily (e.g., Lee *et al.* 2012). Thus, research students learn autodidactically or from their supervisors in the 'research apprenticeship' model (Monk *et al.* 2012). Students do not learn in a group with specialist instructors, forfeiting the benefits of interacting with experts in diverse areas and reinforcing understanding through peer learning (Dresner 2008; Evans and Stevenson 2010). Furthermore, this model of postgraduate education encourages the 'vanishing act' (Fincher 2012), whereby students work at home, in isolation, and often become unsure of their progress, as Ross *et al.* (2011) reported in relation to writing skills. Other problems, including the social isolation felt by some international students (Erichsen and Bolliger

2011) and a low academic self-concept (Curtin *et al.* 2013), are exacerbated by withdrawal from the campus environment and can also contribute to poor progress.

While some supervisors counter this with informal mentoring, this is often *ad hoc* (Fincher 2012) and depends very much on the supervisory skills and commitment of the supervisors (Brew and Peseta 2009). It also assumes the supervisor's competence in all core areas, which may require that the supervisor gain competence in new skills (Mohan and Radhakrishnan 2011). Thus, successful supervision depends heavily on the skills of the individual supervisor. Furthermore, recent research has identified the value of 'collective academic supervision', with multiple supervisors working with students to create the best environment for students to learn core academic competencies (Nordentoft *et al.* 2013). This can also balance the 'tough love' approach of some supervisors, who deliberately create a critical environment for their students who need to rise to the expectations or leave (Aitchison *et al.* 2012).

Many overseas universities and some disciplines in Australian universities have responded to these evolving requirements for providing fundamental skills to research students with postgraduate courses within higher degrees by research to cover critical learning skills, provide peer-learning interactions amongst students and expose students to a wide range of subject experts (e.g., Maxwell and Shanahan 1997; Sarros *et al.* 2005; Stephenson *et al.* 2006; Rolfe and Davies 2009; Chiteng Kot and Henda 2012). These are known variously as research-coursework doctoral programs (Trigwell *et al.* 1997), professional doctorates (Chiteng Kot and Henda 2012), professional research doctorates (Nerad 2007), or work-based doctorates if they involve significant practitioner liaison (Costley and Lester 2012). Usher (2002) sees these developments as responding to changes in employer expectations of graduates: 'If knowledge is the currency of the new economy, universities are inevitably involved in its production. Their activities are knowledge intensive. They are also critically involved in the formation of those who take their place in this economy as knowledge workers. This means that universities have to ensure that these workers take their place with the right amount and kind of human capital -- with in other words the right skill set. Government and society, rightly or wrongly, now demand no less.'

Here, we contrast two models for doctoral education: the research model that requires no coursework and the mixed research and teaching model (embracing both coursework within the traditional degree and a distinct research-coursework doctoral program, using Trigwell *et al.*'s (1997) terminology. This illustrates the challenges in providing effective postgraduate education in fisheries science, wildlife management and conservation biology without formal postgraduate courses. We focus on training in quantitative methods given our knowledge and interests, although other disciplines are relevant. Part of this knowledge was developed through building quantitative training in a project funded by the Fisheries Research and Development Corporation of Australia, the Department of Fisheries Western Australia and Murdoch University (Pollock and Loneragan 2013). We argue that including relevant coursework will improve Australian graduate education in these disciplines, as part of the traditional research PhD or as a research-coursework doctoral program.

Why is this important?

The health and vitality of the related professions of fisheries science, wildlife management and conservation biology are crucial to the Australian economy and to Australian society (e.g., Beattie 1995; Bunn *et al.* 2007; Kirkpatrick 2011; Prowse and Brook 2011; Wardell-Johnson *et al.* 2011). Natural resources management, which faces increasing challenges (Box 1), depends on sound science.

Natural resource scientists working in agencies and universities need to be well educated in every area in Box 2, not just in their discipline. In general, successful graduate research programs across the sciences internationally have a diverse disciplinary base (Kroll 2007; Newing 2010; Vinhateiro *et al.* 2012) or a strong industry focus (Bissonnette *et al.* 2000; Ladesic *et al.* 2012).

The interdisciplinary nature of fisheries science, wildlife management and conservation biology: implications for education in Australia

The interdisciplinary nature of these sciences creates special problems in education. Undergraduate students receive introductory overviews on all the topics in Box 2, but degree requirements and time pressures preclude in-depth treatment. For example, Dickman and Crowther (2009) include brief descriptions of hypothesis testing, Bayesian analysis, information-theoretic approaches, animal ethics

Box 1. Some natural resource management challenges in Australia.

- Habitat degradation and loss
- Effects of climate change
- Development due to populations growth, mining, oil, natural gas exploitation and other infrastructure
- Marine and National Parks establishment and maintenance
- Threatened species (freshwater fish, marsupials and monotremes)
- Exotic species introductions
- Over exploitation of fish stocks by commercial and recreational fishers
- Fisheries sector (recreational vs. commercial) allocation issues

and publishing science in their chapter on scientific method in an introductory textbook. This raises awareness, but does not equip students with the ability to apply these skills. Some skills are reinforced in advanced units, but many students could enter postgraduate study with only limited awareness and poor skills in important areas.

To check the minimum preparation of students in quantitative skills after their undergraduate degrees, in September 2012 we consulted online handbooks to document the required quantitative units in seven randomly chosen Australian undergraduate degrees in wildlife ecology/ecology, conservation biology, or marine science. We considered marine science because we know of no majors in fisheries science and marine science is a major source of fisheries postgraduate students. While quantitative skills may be integrated in other units within these courses and students can enrich the minimum requirement with electives, we found the level of preparation highly variable. Many students take an introductory statistics unit only, or an introductory statistics unit plus an experimental design unit (Appendix 1).

Therefore, almost all the education in quantitative methods occurs at the postgraduate level, followed by continuing education in the work place. Students enter postgraduate programs from varied backgrounds with uneven expertise in component 5 of Box 2 (quantitative science) and, although we have no data, we suspect that this is also true of component 4 (human dimensions, which deals with social research skills, media liaison, politics and governance, and environmental ethics). This contributes to 'statistical confusion' amongst graduate students, who may fail to integrate study design, analysis and writing (Boyles *et al.* 2008).

We now consider how the postgraduate education in these fields should be structured. We contrast the Australian model with that of the US, where a European influence has been stronger compared to the influence of the United Kingdom on the Australian model (Evans 2007).

Box 2. Components of fisheries and wildlife Science showing the interdisciplinary nature of the fields.

1. Basic biology
2. Fisheries or wildlife biology
3. Environmental science
4. Human dimensions
5. Quantitative science
    a. Mathematical modelling
    b. Statistical modelling
    c. Computational Skills

Contrasting models of university education: Australia and the United States.

The Australian system has adopted the one-year Honours course, often mainly by research, at the end of the BSc as a 'fast track' preparation for a graduate research degree, in contrast to the two-year Masters degree common elsewhere (Evans 2007; Dobson 2012). By contrast, the US model uses coursework more extensively. In Box 3, we show the major components of each system in a simplified form.

The differences are striking. Most Australian students require no formal coursework after the undergraduate degree, whereas in the United States, formal coursework continues from BSc to PhD. Australia gives students narrowly focused training, with more emphasis on research thesis training and less on coursework. We believe that the traditional, research-only model causes special challenges for interdisciplinary fields, particularly for quantitative methods. Of course, the US model is not without critics, with their concerns centred on:

- "Doctoral students are educated and trained too narrowly.
- They lack key professional skills, such as collaborating effectively and working in teams, and have no organizational and managerial skills.
- They are ill prepared to teach.
- They are taking too long to complete their doctoral studies and in some fields, many do not complete their degrees at all.
- Doctoral students are ill informed about employment outside academia." (Nerad 2004).

We note that the same criticisms could be made of the Australian system. We acknowledge these criticisms, but argue that carefully chosen coursework overcomes them – something that the Australian system could adopt from the U.S.

The U.S. system also aligns strongly with the structure of higher education agreed in the Bologna Process, designed to create a European higher education area with better-aligned education structures and standards to facilitate co-operation and the movement of students. It operates on a three-step system of bachelor degree, masters degree, doctorate (European Commission 2013). While the Australian government views the Australian higher education system as also having three steps (bachelor, honours, doctorate), it also recognises the potential problems of (i) recognition of Australian qualifications if the European professional standard becomes a bachelors degree followed by a masters, and (ii) potential problems for Australian honours graduates seeking direct entry to European PhDs (Department of Education, Science and Training 2006). More coursework, and a re-examination of the role of the honours degree (see critiques in Zeegers and Barron 2009; Manathunga *et al.* 2012) may be needed to maintain opportunities for Australian students

Box 3. Standard academic pathways for natural resource scientists in Australian Universities compared to those in the United States. These are contrasting models for postgraduate education.

Australia	United States
BSc 3 years by coursework	BS 4 years by coursework
BSc Hons I year by research thesis	MS 2-3 years coursework, research thesis mix
PhD 3-5 years by research thesis only Total time ~7-9 years Coursework time ~3 years Research time ~4-6 years	PhD 3-4 years coursework thesis mix Total time ~9-11 years Coursework time ~6 years Research time ~3-4 years

Note- There are masters degrees given in Australia but the B Sc. Hons and then directly to PhD is still the standard pathway. There may be some coursework in some Australian PhD programs but what we have presented are roughly the norms for Australia and the United States.

internationally and to attract international students to Australia. The honours degree is also under critical examination in the United Kingdom (Yorke *et al*. 2008).

The University of Tasmania has already moved to a mixed model of postgraduate education in a closely related field, with their PhD in quantitative marine science (including a fisheries component), where formal coursework comprises about one third of the requirements. Business, psychology and education academic programs in Australia have already recognised the importance of relevant coursework in higher degrees through developing explicit Doctor of Business Administration, Doctor of Psychology, Doctor of Education and Doctor of Clinical Psychology degrees: Chiteng Kot and Henda (2012) estimate that about 20 of these are on offer in Australia now. These all require advanced coursework, usually focused on research methodology, which is completed before students undertake a major research project. For two Doctor of Psychology degrees, the coursework meets the Australian Psychological Accreditation Council's accreditation requirements. Although the education and business degrees may not seek professional accreditation, they do focus on practical skills and applied problems, which Chiteng Kot and Henda (2012) acknowledge are strong reasons for adopting such degrees. According to Trigwell *et al.* (1997), the coursework component of these degrees varies from 17% to 67%.

A key to the professional doctorate approach is placing professional practice centrally (Maxwell and Shanahan 1997). While there has been some confusion about the relative emphases of professional doctorates compared to the research PhD (Sarros et al. 2005), they nevertheless ground students thoroughly in research methodology via coursework. We believe that the education of Australian postgraduates in the natural resource fields should emulate this approach, but it will take time and resources to achieve this.

Short courses and workshops

The main advantages of short courses are lower cost, flexibility and the ease of repeat delivery at different times in different places. They integrate well with the current Australian postgraduate education system. However, it is difficult to demonstrate improved learning in the absence of formal assessment and the time for learning is short, which probably leads to lower retention of learning in short courses compared with semester long teaching.

Postgraduate students and continuing education of professionals are two distinct markets for short courses. We need to consider carefully whether all groups should be taught together, or whether workshops should be designed separately for different sectors/groups/target participants. For example, an argument could be made for a two-week short course on key quantitative methods in fisheries aimed primarily at new postgraduate students. It could cover many methods and include projects and assessment. For professionals, however, it makes more sense to focus on short (e.g., three-day) workshops on core topic components because of the participants' time limitations. Shorter workshops also minimise costs such as accommodation for students travelling to participate, as well as easing the logistical constraints on the availability of venues. Very advanced topics, with a narrower appeal, could be taught to mixed audiences of postgraduate students and professionals.

A crucial feature of workshops is who is to pay for them. We argue that universities should pay for their postgraduates to attend a two-week workshop on core topics. We believe that this model of long workshops with assessment is so crucial to improve postgraduate education that universities have a duty to provide it until they put semester long units in place. We believe that participants should pay some of the cost for advanced workshops aimed at both postgraduate students and continuing professionals, but key agencies and

universities should subsidise them. This is especially true when international presenters in specialised disciplines are used and travel costs are high.

Workshops may be delivered in person, distance/online, or a combination. While distance education is cheaper, we suggest that it is not as effective as in person delivery for technical subjects, where students benefit from immediate feedback and peer learning. A combination of distance education and in person workshops may be valuable. For example, postgraduate students from multiple universities could assemble for a two-week intensive workshop at the start of their program and then complete online modules later. A better understanding of the potential for such online elements may come from an evaluation of pioneering work (Edge and Sanchez 2011).

Quantitative science

In an ideal world all PhD students in fisheries, wildlife, population ecology and conservation biology would include these topics in their PhD: two semesters of basic statistical methods, one semester of sampling animal populations, one semester of population dynamics/ stock assessment and perhaps one or more additional statistics classes in multivariate analysis, spatial statistics or nonparametric statistics (Box 4). They would also need a GIS class and basic calculus. This is a benchmark for Australian programs to reach a high international standard. Students who aspire to working more on quantitative methods at the interface of mathematics, statistics and biology would need training in differential equations, matrix algebra and mathematical statistics.

Linkages to other related disciplines

Many of the quantitative methods described above are relevant to many disciplines. For example, a mathematical population dynamics class, or a sampling animal populations class, could be taught to postgraduate students in fisheries science, wildlife biology and conservation biology. We also believe many specialised biological courses (such as advanced genetics techniques) or human dimensions courses could be taught this way. Communication between these related professions needs to be improved so that postgraduate education can be developed along these lines.

Some suggestions for a new Australian model for teaching postgraduate fisheries science and conservation biology

In our opinion there are ways to build a superior Australian system of postgraduate education. It should use information from overseas and from other disciplines adapted to Australian realities. Some general bases for a solution might be: first, to recognise that Australian universities are severely underfunded (OECD 2011), especially in providing quality postgraduate education; and second, reform postgraduate education to achieve economies of scale recognising the "tyranny of distance" and the small size of the Australian population – features distinguishing Australia from the United States and European postgraduate systems.

Box 4. Important components of quantitative science for all PhD students and professionals in natural resource sciences.

Mathematical modelling

Basic mathematics

(calculus, matrix algebra, simple differential equations)

Population dynamics models (introduction)

Stock assessment methods (introduction) for fisheries students

Statistical Modelling

Basic statistical methods (Analysis of Variance and experimental design, Multiple Regression, nonparametric methods)

Basic sampling methods

Sampling animal populations

Generalised Linear Models (introduction)

Spatial statistics (introduction)

Multivariate methods (introduction)

Computational Methods

Microsoft Excel and basic statistical packages

GIS packages such as ESRI ArcView

R programming

Note- The requirements for PhD students specialising in quantitative methods would be much more than these topics. The additional work would include two semesters of mathematical statistics and possibly an introductory class in Bayesian statistics.

We believe that the current Australian model of BSc + Hons + PhD (Research Thesis) (Box 3) is not working well and that three alternative models should be considered carefully:

1. BSc + 2 yr Masters (Coursework and Research Thesis) + PhD (Research Thesis)
2. BSc + Hons + 1 yr Masters (Coursework) + PhD (Research Thesis)
3. BSc + Hons (Coursework? and Research Thesis?) + PhD (Coursework and Research Thesis)

We believe that completing the requirements of a masters degree, as in model 1 or 2 above, is necessary to reach a minimum professional level as a wildlife or fisheries biologist. Therefore, degree paths that include strong masters degrees

should probably become the norm. Students could stop at that point and have a very satisfactory education and career or continue for the PhD to focus on research. If students reached this masters level, they would also reach the level needed for accreditation if that became a requirement for membership in professional societies. However, we have not considered or discussed accreditation for the natural resources disciplines here. Model 1 has the strong advantage of close alignment with the Bologna Accord, while Model 3 is the one favoured by other fields such as education.

Including formal coursework, as in models 2 and 3, offers more time to learn and therefore provides stronger reinforcement and longer retention of learning, more effective assessment and greater opportunities for different learning approaches such as peer learning. While coursework is costly, less flexible and more difficult to integrate into the current style of Australian postgraduate research degrees relative to short courses, we believe that the advantages of coursework outweigh these problems.

One valuable reform would be to construct postgraduate consortia that span multiple universities and are based on deep, mutually beneficial co-operation. These postgraduate consortia could teach postgraduate semester long courses, such as those offered in major universities in the United States. The courses would most likely have to be offered using a mixture of in person and distance education to be effective. Distance education can be part, but not all, of the solution. Thus, some members of a consortium might be relevant to different geographic regions of Australia (e.g., Western Australia, south-eastern Australia, Queensland). This should allow students to study subjects aligned closely with their research themes, which Raman (2008) claims is vital in ensuring student engagement.

One advantage would be that universities could share the costs of specialists in quantitative methods. Although we have not done any formal assessment, it is our experience that specialists in sampling animal populations, fisheries stock assessment models, ecosystem models, or spatial models are rare in Australian universities. We also believe that specialists are needed in other areas such as applied molecular genetics.

Some existing Australian inter-university collaborative models for postgraduate students in other disciplines show how this might be achieved for quantitative methodologies in natural resources. For example, medical statistics, now commonly named biostatistics, has a severe shortage of professionals. Medical statisticians created the Biostatistics Collaboration of Australia (http://www.bca.edu.au/), involving statistics groups at seven Australian Universities (University of Queensland, University of Newcastle, University of Sydney, Macquarie University, University of Melbourne, Monash University and the University of Adelaide). They offer diplomas and masters degrees in biostatistics with part time and distance education options. No single university could provide all the resources alone. Some aspects of this model may be suitable for fisheries and wildlife science. One weakness of the biostatistics model is the almost exclusive use of distance education, reducing opportunities for prompt feedback and peer learning.

Another feature of the solution will be to enhance existing linkages and build new ones between universities in Australia, Europe and North America where there are substantial numbers of fisheries and wildlife scientists. This would require enhanced funding for visits in both directions and help engage more international specialists in Australian fisheries, wildlife and conservation biology postgraduate education and research.

In their assessment of research-coursework doctoral programs in Australian universities, Trigwell *et al.* (1997) singled out the Education Doctorate degree from Deakin University as 'exemplary'. The coursework included 'Professional Journal Writing, Critical Reflective Writing, Critical Review of Literature 1 and 2, Research Methodology 1 and 2, and Proposal Writing 1 and 2. ' They also note that high-quality doctoral programs requiring coursework, 1) outline clearly the relative contributions of the coursework and the research components, 2) demonstrate how the coursework will improve candidates' understanding of practical research issues, 3) involve relevant professionals or professional bodies as well as university faculty, 4) offer all coursework and research components at a very high level, and 5) include sufficient flexibility to accommodate full-time and part-time students. Although the content of research methodology coursework would obviously vary between education and natural resources management, the description provided by Trigwell *et al.* (1997) provides a compelling outline of our vision for postgraduate education in natural resources management in Australia.

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APPENDIX I

Summary of undergraduate units on quantitative methodology offered in degrees of wildlife ecology/ecology, conservation biology, and marine science at seven Australian Universities. Details were taken from online handbooks in September 2012.

University	Course	Compulsory Quantitative Skills Units
La Trobe University (Melbourne campus)	BSc (Wildlife and Conservation Biology)	STA1LS *Statistics for life sciences* – This subject provides an introduction to applied statistics, and strengthens basic numeracy skills. It introduces students to the basic applied statistical methods used in the biological sciences, medical sciences, agricultural sciences, nutrition, and health sciences. The three main areas of study are descriptive statistics, probability, and statistical inference and the use of a statistical computing package is an integral part of this subject. This subject is a possible pre-requisite for the second-year subjects in statistics.
		BIO2POS *Practice of science* – The subject provides an introduction to the practice of science and is core for a range of 3rd year science subjects. It explores how science proceeds and how to identify scientific questions. It examines the purpose of null and alternative hypotheses, how to design experiments and explores sampling methods. The course has a strong emphasis on statistical testing of hypotheses. Students will learn the mechanics and limitations of a range of important statistical tests, allowing them to choose appropriate tests and interpret and critically assess the reliability of experimental results. The course will explore the conventions of written and oral scientific communication and the challenges of communicating science to the general public and policy makers. Finally, students will be introduced to ethical behaviour in the practice of science.
Deakin University	Bachelor of Environmental Science (Wildlife and Conservation Biology)	SLE101 Techniques in environmental science – This unit emphasises skills for the collection of environmental data in the field. Field skills developed will include animal and/or plant identification and the use of keys, field survey and monitoring methods, and quantitative assessment techniques. Methods for the analysis of environmental data, interpretation and presentation will also be covered. Newer techniques such as global positioning systems (GPS), geographic information systems (GIS) and remote sensing will be discussed.
		SLE226 Research methods - The design of ecological experiments and analysis of ecological data are critical skills required by all ecologists. This unit is devised to step students through the process of ecological research from initial project conception through to manuscript preparation. This unit comprises a series of lectures and practicals aimed at developing skills in experimental design, data analysis (using statistical software) and data presentation (both written and oral). A strong emphasis will be placed on a group research project. This unit aims to develop a strong understanding of the following aspects of ecological research: design and implementation of ecological research projects; developing an understanding of why we need to research ecological phenomena; analysis of ecological data; reporting ecological research (both written and oral).

APPENDIX 1

University	Course	Compulsory Quantitative Skills Units
Griffith University	BSc (Ecology and Conservation Biology)	1003ENV Statistics - This course provides an introduction to the basic concepts and practices of data analysis and inferential statistics. It will provide an understanding of several techniques including testing one or more means from sampled populations (t-Tests and ANOVAs), relationships between scale variables (correlations and regression), and contingency table analysis (Chi-square tests). The course places emphasis on understanding the use of appropriate data for these tests, the use of exploratory data analysis, and the underlying distributions and assumptions associated with these tests. Students will learn how to carry out these tests by hand, via the use of a statistical software (SAS or SPSS), check assumptions, interpret results and report findings in plain English.
		1002ENV: Applied Mathematics - This course provides a basic foundation in applied mathematics. The topics covered include algebra; linear, quadratic, trigonometric and logarithmic functions; vectors and matrices; and various calculus techniques (differentiation, integration and separable differential equations). The application of these topics to real world phenomena is integral to this course. Assessment is by problem solving exercises, mid semester and final examination. OR
		1201BPS Mathematics 1A - The course revises and extends basic integral and differential calculus of one variable, introduces partial derivatives and basic vector algebra in two and three dimensions. It provides a foundation for later studies in mathematics and science.
		2291ENV Experimental design and statistics - Environmental research typically involves the collection of data and subsequent statistical analysis. Good research which enables valid conclusions, requires consideration of experimental design and appropriate statistical analysis. This course presents the basic principles of experimental design together with a range of commonly used statistical methods. Through the completion of a project, students experience all aspects of the quantitative process from question definition and initial exploratory data analysis, through formal statistical inference, its interpretation in terms of an original research question, and the implications of underlying assumptions and resulting limitations. The use of commercial statistical software enables real experiences of data management and analysis.
		3047ENV Geographic Information Systems - Geographic Information Systems are essential tools for the management, analysis and presentation of spatially referenced data. This course addresses methodological concepts of GIS, technical and organisational issues, as well as practical applications in environmental sciences and planning.
Murdoch University	BSc (Conservation and Wildlife Biology)	MAS183 Statistical data analysis - This unit introduces students to methods of collection and statistical analysis of data of particular relevance to the life and health sciences. Topics: numerical and graphical description of data, design and analysis of simple experiments, probability and sampling distributions, introduction to statistical inference, statistical analysis of relationships, non-parametric methods, interpretation of output from statistical software, interpretation of statistical reporting in scientific literature.

APPENDIX I

University	Course	Compulsory Quantitative Skills Units
Edith Cowan University	BSc (Conservation and Wildlife Biology)	MAT114 Introductory statistics - This unit deals with the methods and skills of organising, summarising and presenting numerical data. The concepts of estimation and hypothesis testing are studied, with the emphasis on analysing real data. Calculators and statistical software are used throughout the unit.
University of New South Wales	BSc (Ecology)	MATH1041 Statistics for life and social sciences - Probability, random variables, independence. Discrete distributions, Poisson and binomial distributions. Data analysis, Descriptive statistics. Sampling, Continuous distributions, the normal distribution. Estimation of mean and variance. Tests of hypotheses. Linear regression and correlation. Tests for goodness of fit. Bayesian statistics.
		BEES2041 Data analysis for life and earth sciences - Development of skills in applying statistics to biological, earth and spatial data; design and analysis of experiments in life and earth sciences; sampling strategies for estimating sample size; analysis of community and environment structure using multivariate statistics; simulation modeling in population biology, and statistical fitting of non-linear models to population growth data; correlation and both simple and multiple regression; improving statistical models using analysis of residuals; analysis of spatial data.
University of Tasmania	Bachelor of Marine Science	KMA153 Data handling and statistics 1 - Introduces the management and interpretation of quantitative information. A 'hands-on' course, developed using data which is drawn from disciplines of relevance to the students. Topics include: collecting, processing and presenting quantitative information; descriptive statistics for summarising data; data exploration techniques; the role of chance; sampling; commonly used statistical methods. Interpreting statistical information; mathematical skills; the concept of modelling; use of computers and spreadsheets in mathematical and statistical applications.
		KMA253 Data handling and statistics 2 - Extension of the themes introduced in KMA153 by examination of problems involving several treatments or several explanatory variables. The unit covers properties of designs and tests; regression; multiple comparisons and analysis of variance; and an introduction to principles of statistical modeling. Students are expected to use and interpret the output of a contemporary statistical package, appreciate some problems of real data from observational studies and carry out analyses and write reports directed towards the concerns of a given experiment or study.
		KZA357 Quantitative methods in biology - Quantitative skills are among the fundamental tools of professional zoologists and other biologists. They are necessary to design their studies, analyse and interpret their data, and to assess and interpret published studies. This unit provides a solid grounding in appropriate ways to collect and analyse common types of data in biology and ecology. It emphasises hands-on, practical experience with commonly used statistical software and addresses the problems most often encountered in dealing with biological and ecological data. The unit covers basic sampling and experimental design, data analysis using standard univariate techniques (e.g. analysis of variance and covariance, regression, analysis of categorical data) and introduces multivariate techniques for both pattern exploration and hypothesis testing. This unit is strongly recommended for ecology and environmental science students and those considering Honours.